

BioSIGHT: Interactive Visualization Modules for Science Education

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1. Description

Redefining science education to harness emerging integrated media technologies with innovative pedagogical goals represents a unique challenge.

The Integrated Media Systems Center (IMSC) is the only engineering research center in the area of multimedia and creative technologies sponsored by the National Science Foundation. The research program at IMSC is focused on developing advanced technologies that address human-computer interfaces, database management, and high-speed network capabilities. The BioSIGHT project at IMSC is a demonstration technology project in the area of education that seeks to address how such emerging multimedia technologies can make an impact on science education. The scope of this project will help solidify NASA's commitment for the development of innovative educational resources that promotes science literacy for our students and the general population as well. These issues must be addressed as NASA marches towards the goal of enabling human space exploration that requires an understanding of life sciences in space.

The IMSC BioSIGHT lab was established with the purpose of developing a novel methodology that will map a high school biology curriculum into a series of interactive visualization modules that can be easily incorporated into a space biology curriculum. Fundamental concepts in general biology must be mastered in order to allow a better understanding and application for space biology. Interactive visualization is a powerful component that can capture the students' imagination, facilitate their assimilation of complex ideas, and help them develop integrated views of biology. These modules will augment the role of the teacher and will establish the value of student-centered interactivity, both in an individual setting as well as in a collaborative learning environment. Students will be able to interact with the content material, explore new challenges, and perform virtual laboratory simulations.

The BioSIGHT effort is truly cross-disciplinary in nature and requires expertise from many areas including Biology, Computer Science, Electrical Engineering, Education, and the Cognitive Sciences. The BioSIGHT team includes a scientific illustrator, educational software designer, computer programmers as well as IMSC graduate and undergraduate students. Our collaborators include TERC, a research and education organization with extensive k-12 math and science curricula development from Cambridge, MA.; SRI International of Menlo Park, CA.; teachers and students from local area high schools (Newbury Park High School, USC's Family of Five schools, Chadwick School, and Pasadena Polytechnic High School).

2. Project Plan

The long-term goal of this project effort is to develop interactive visualization tools that can be adopted in *all* curricula, implemented by a wide range of teachers with varying levels of technical expertise, and can be used by schools with limited technological means. In order to achieve this ambitious goal, the first step involves the development of a prototype pilot module. The development of a prototype pilot module will illustrate a proof of concept for the design and implementation of the lesson content that is strongly coupled with the desired interactive technology features. Furthermore, we will initiate testing of the prototype pilot module, initially with small groups of high school students and teachers, and gradually expanding to the entire classroom. The data obtained will provide the basis for the formative evaluation of this effort in assessing the effectiveness of technology in education. In addition, this data will provide valuable feedback to the visual and technology design teams that are required for future iterative revisions.

BioSIGHT in collaboration with TERC of Cambridge, Mass. will develop the architecture of the modules that incorporate an innovative pedagogical strategy. The structure of the BioSIGHT modules includes three components: (i) an **exploratory challenge** that introduces concepts in the form of a puzzle to motivate and engage students; (ii) an **interactive storyboard** that utilizes advanced multimedia tools to interactively convey content for exploration; and (iii) an **interactive laboratory** in which students can participate in simulated experiments. We will identify the learning outcomes and measure the impact on students and teachers.

The BioSIGHT lab will become an additional node to the current Media Immersion Environment (MIE) systems integration experiment. The MIE represents a unique opportunity to assess the effectiveness of a collaborative learning pedagogical strategy using interactive visualization tools that are delivered over a high bandwidth network.

3. Related Work

Inquiry-based curricula do exist and have been well received by the education community. For example, NSF funded projects from BSCS, EDC, and TERC have all helped reframe our view of high school biology curricula. [1,2,3] Such curricula address the needs of the broadest range of schools, but have up to now avoided ambitious technological components. These inquiry-based curricula need improvement on many fronts, including scientific visualization. Students often have difficulty in forming robust mental models of fundamental cellular and molecular processes because they lack the visualization cues essential in developing such models. With traditional educational tools these processes are conveyed through discrete, static illustrations when in fact, they are interrelated, dynamic processes bursting with activity that brings cells and organisms to life. Multimedia products currently on the market (Videodiscovery, Bio-Animate, LOGAL's Explorer), whether in the form of videotape, laserdisc, or CD-ROM do little more than lecture with moving images, in which the pace and the flow of the information has been predetermined to a great extent by the

designers. Consequently, students are not challenged to form their own models of these processes, nor asked to demonstrate their understanding through meaningful assessments.

4. Accomplishments

Developed a prototype pilot module with content emphasis on the immune system

The national frameworks have articulated the importance of scientific thinking and inquiry skills as fundamental elements of the science education needed for the future.[4,5] BioSIGHT, in collaboration with TERC, has identified a pedagogical goal of interactive scientific visualization as a tool to promote the formation of visual metaphors for abstract concepts that are inaccessible because of temporal or spatial scale. This element served as the foundation for the identification and development of appropriate visual content for the **interactive storyboard** component of the module. The process involved preliminary conceptual sketches into storyboard formats and subsequently the development of fully realistic 3-D animations with narration to accompany each lesson. A user friendly interactive interface was developed that facilitates navigation within a topic as well as among several different topics within the *Immunology* prototype pilot module. In addition, the interface also enables navigation to either the **exploratory challenge** or **interactive laboratory** component of the prototype pilot module. Figure 1 illustrates screen captures from the prototype pilot module.

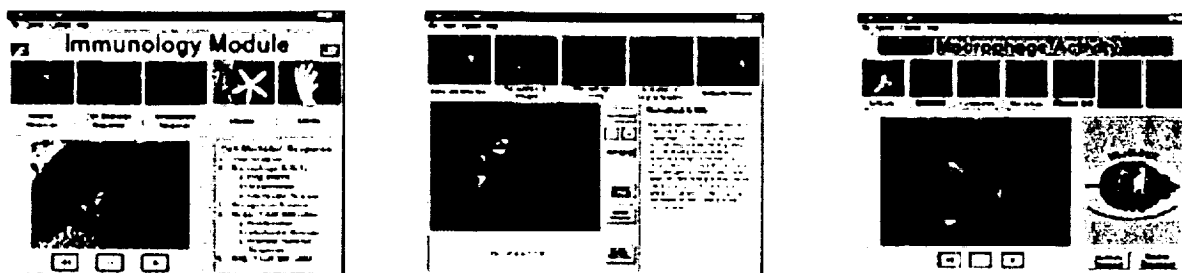


Figure 1. Screen captures from the prototype immunology module showing the introduction to the lesson, the interactive storyboard, and the cast of characters.

Developed a prototype Virtual Microscope

For the **interactive laboratory** component of the module, we have developed a prototype of the *Virtual Microscope* with interactive features such as moving the microscope stage, focusing, and zooming to various magnification levels to enable a realistic digital emulation of a light microscope stage. The development of this visualization tool permits detailed examination of minute cellular structures that are invisible to the naked eye, thus conveying the concept of scale. In addition, we have completed an interactive tutorial for the *Virtual Microscope* that will accompany the **interactive laboratory** component of the module. Figure 2 illustrates screen captures of

the *Virtual Microscope*. The development of the prototype has enabled the identification of the technical challenges associated with providing real-time interactivity, which led to the on-going interactions with the research program.

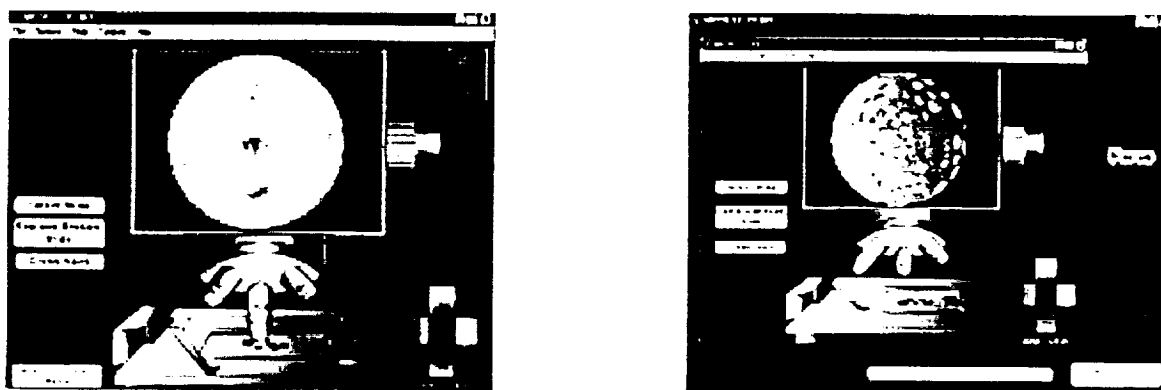


Figure 2. Screen captures from the prototype *Virtual Microscope* and tutorial within the **interactive laboratory** component of the module showing the interface and a portion of a tiled image generated from real microscope images.

There are several technical challenges associated with the development of a software engine that is required to provide real-time responses for a typical light microscope that the interactive laboratory component will address. First, there is a limited field of view as one looks through the objective of a real microscope, and consequently many images are required to capture and represent an entire slide specimen. Very large seamless images reconstructed from several smaller images must be generated through an innovative **tiling process** developed in the **Computer Interfaces** area. The implementation of this algorithm is critical in the development of a high resolution digital image archive derived from actual images collected from a microscope. Such high resolution images require an enormous amount of storage capacity, a luxury that is not available to classrooms equipped with inexpensive computing equipment. The integration of **compression** technology is also required. It encompasses novel methods that have been developed in the **Media Communications** area to utilize cues from human perception in order to eliminate the artifacts. To maximize real-time response, the compression algorithms will selectively decompress the region of interest based on the user's input, rather than the entire image. Furthermore, a problem in the management of multimedia information involves the indexing of image, video, and audio **databases**. Researchers in the **Information Management** area are developing a methodology to automatically extract such information based on content. This approach combined with the compression technology described above will allow users to effectively search a remote database and quickly retrieve information for real time interactivity.

Performed informal classroom assessment at Newbury Park High School

The informal testing that we conducted at Newbury Park High School provided an opportunity for students currently enrolled in the sophomore level biology course and teachers to explore our prototype pilot module. In addition, it provided a mechanism for receiving invaluable feedback and comments that we can use for the revision of the prototype pilot module as well as the development of subsequent modules.

The format of the informal assessment involved a video-taped session of a pre-interview, followed by an opportunity to explore and familiarize themselves with the prototype pilot module, and concluded with a video-taped post-interview session. These video-taped sessions are available upon request. Some example pre-interview questions for students included favorite subject, comfort level with computers, and identification of several challenging aspects of biology that they have encountered; pre-interview questions for teachers included difficult topics for students and what teachers perceive as learning barriers for their students. Some example post-interview questions for students included interface and learning preferences, what additional features might be useful, as well as whether the prototype pilot module was able to explain abstract concepts; post-interview questions for teachers included interface and use preferences as well as classroom management issues in terms of how they would implement this material as part of their teaching technique.

5. Future Directions

We are planning on expanding the scope of the content in the prototype pilot module as well as the initiation of a formative evaluation and assessment conducted by our collaborators at SRI International. We anticipate providing our collaborating schools with a version of the module that can be implemented as part of their current course work.

The development of the prototype pilot module is a step in the direction that will allow us to address the *process* in which students interact with these modules. It will be our research instrument that allows us to better understand and quantify the effect of multimedia technology and innovative educational software materials on science education.

6. References

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